Fermilab Directorate

MEMORANDUM OF UNDERSTANDING

FOR THE 2006 MESON TEST BEAM PROGRAM

T-958

The FP420 (CMS+ATLAS) Fast Timing Group

May 31st 2006

INTRODUCTION

This is a memorandum of understanding between the Fermi National Accelerator Laboratory and University of Texas at Arlington (UTA) and the University of Alberta experimenters who have committed to participate in beam tests to be carried out during the 2006 Meson Test Beam Facility program. The memorandum is intended solely for the purpose of providing a budget estimate and a work allocation for Fermilab, the funding agencies and the participating institutions. It reflects an arrangement that currently is satisfactory to the parties; however, it is recognized and anticipated that changing circumstances of the evolving research program will necessitate revisions. The parties agree to negotiate amendments to this memorandum, which will reflect such required adjustments.

The experimenters require beam time at Fermilab during the 2006 Meson Test Beam Run to test charged particle detectors with very high timing resolution, $\sigma(t) \sim$ 10-20 ps. The primary goal of such detectors is to measure the time-of-flight of leading (diffractively scattered) protons at the LHC (CMS and/or ATLAS) 420m from the collision point. The experimenters aim to measure at the LHC the exclusive process pp $\rightarrow$ p + H + p where H is the Higgs boson. Observation of this process, which appears feasible but difficult, will enable the Higgs boson mass to be measured with a resolution ~ 2 GeV per event, measure its spin and CP (expected to be 0++), its coupling to gg (through a top-loop in the Standard Model) and its width (if $\Gamma(H) > \sim 3$ GeV). As the cross section is expected to be small, 1 – 10 fb for Standard Model Higgs (but possibly much larger in SUSY scenarios), it is imperative to use high luminosity with many interactions per beam crossing. One of several methods of reducing pile-up background, where the two protons and the central JJ/WW/ZZ are not all from the same event, is to have precision timing on the two forward protons relative to each other. A time resolution of 20 ps will give a 6 mm $\div \sqrt{2}$ = 4.3 mm resolution in z(interaction), if the protons came from the same interaction. This z(pp) must match z(vertex) from the JJ/WW/ZZ event.

The experimenters plan to test two types of detectors, using Cerenkov light in both cases.

One, QUARTIC, uses a fused silica (similar to quartz) radiator in the form of small bars, typically 6mm x 6mm x 20mm inclined at the Cerenkov angle $\theta \sim 50$ deg, so that some light (emitted at the right azimuth angle ϕ) travels straight along the bar (20mm direction) and through a short air light guide (an aluminized box 6mm x 6mm x ~ 80mm) onto one pixel of a Micro-Channel Plate Photomultiplier (MCP-PMT). The particle will pass through 8 such bars, and there will be two rows (horizontal, x-dimension), so 2 x 8 = 16 pixels of area 6mm x 6mm will be read out. In the final detector there will be either 4 rows in x (4 x 6mm = 24mm full width) or there could be more, finer, x-bins (up to 16 1.5mm bins). The latter case becomes interesting at high luminosity if there are two or more particles in the detector from the same bunch crossing. Then two separated protons are detected as 8-pixel "tracks", each separately timed. This idea of a "tracking TOF counter" is without precedent.

The second type of detector, GASTOF, is a gas (atmospheric pressure) Cerenkov counter, about 20 cm in length and 8 mm x 24 mm in cross section (the prototype to be tested is larger in transverse dimensions). The Cerenkov light is emitted at a small angle and is reflected from a 45 degree mirror at the back onto a MCP-PMT (the same as for the QUARTIC). All the light arrives at the photo-cathode within about 2 ps. The pixels of the MCP-PMT are combined together as a single channel. Both QUARTIC and GASTOF appear promising and will be developed; they have somewhat complementary strengths. It is possible that both could be used in FP420, with a GASTOF (little material) before the final tracking station and one or two QUARTICs behind. The experimenters may test different gasses, but the default gas is perfluorobutane, C4F10

This Memorandum outlines a plan for test beam time during 2006. The experimenters plan to carry out initial tests in July 2006, and expect to ask for a further period in Fall 2006. Results will determine whether both QUARTIC and GASTOF detectors will be incorporated in the proposed LHC experiment, or if one, which type, and with what performance and cost.

I. PERSONNEL AND INSTITUTIONS:

Spokesman and physicist in charge of beam tests: Andrew Brandt, UTA

Fermilab liaison: Erik Ramberg

The group members at present and others interested in the test beam are:

1.1 Fermilab: Michael Albrow

Other Commitments: CDF Analysis, Other roles in CMS and FP420.

1.2 University of Texas, Arlington: Andrew Brandt, Pedro Duarte (student), Arnab Pal (student); Jia Li (engineer)

Other Commitments: Brandt: D0 Experiment ; Duarte: none; Pal: none; Li : ATLAS, ILC

1.3 University of Alberta, Canada : Jim Pinfold, Lars Holm, Drew Price, Jan Schaapman, Yushu Yao.

Other Commitments: ATLAS LUCID detectors (also Cerenkovs).

1.4 UC Louvain, Belgium: Luc Bonnet, Tomasz Pierzchala, Pierre Rodeghiero

Other Commitments: none at this time
Krzysztof Piotrzkowski (team leader): Also in other aspects of FP420

II. EXPERIMENTAL AREA, BEAMS AND SCHEDULE CONSIDERATIONS

2.1 LOCATION

2.1.1 The tests are to be performed in the MTEST beam line, either in the MT6-B2 area inside the climate control hut or in the MT6-B3 area on the motion table. The total length of the detectors along the beam is ~ 1m, including end effects.

2.1.2 The experimenters need a support (table) on which to mount the detectors. This should allow horizontal scanning over ~ 5 cm, which would allow the detectors to be scanned and also to be moved out of the beam line in case there are other users downstream sharing the beam. The experimenters need a cable tray to carry the signal cables from the detector to the fast electronics control area. The experimenters will need some support to align the apparatus relative to the beam line.

2.2 BEAM

2.2.1 BEAM TYPES

The experimenters require only 120 GeV protons, and this is preferred, although any beam momentum above ~ 20 GeV/c would be acceptable. The spot size at the detectors should be less than about 1 cm x 1cm; a few mm in both x and y would be ideal.

2.2.2 BEAM INTENSITY

An intensity of ~ 50K particles per spill is preferred, although any intensity between 10K/spill and 100K/spill is acceptable. Once a good beam condition is established the experimenters have no need to change it (e.g. no momentum scans or changes of particle type).

2.2.3 BEAM CONTROL

The main change in conditions required by the experimenters is a small (~ 10mm) position scan, in steps dependent on the beam spot size. The experimenters require the beam to be steered such that they are able to move the beam across the height and width of the detectors. This means that the Main Control Room operators need to be responsive to requests from the experimenters for small motions of the beam using the elements in M05, including MT5E and MT5V, or that control be given to the experimenters.

2.2.4 BEAM SHARING

Because of limited manpower availability and other commitments the experimenters will be unable to run continuously. They prefer to alternate beam time with other users. The main material in the beam will be 6.5 cm of fused silica (0.5 Xo) and ~ 1 cm more for the beam defining counters. If this amount of material is not compatible with other downstream users, these detectors could be moved sideways out of the beam,

2.2.5 RUNNING TIME

The experimenters plan to make the following studies, initially independently for the QUARTIC and GASTOF counters and finally with both in combination.

(a) Set up trigger with scintillation counters in coincidence with the spill. Time in both "fast anode out" and pixel signals from Burle MCP-PMT's. Incorporate read-out of beam detectors. For each detector:

(b) With beam centrally through Cerenkov detectors, scan in HV, determine the optimal range/value.

(c) With the HV set, scan vertically and horizontally (x-y scan) over area ~ 25mm (hor) x 10mm (vert). Number of positions depends on spot size. The experimenters would aim for 10,000 events (1% statistics) on a 1mm x 1mm grid. With one pulse/minute of 50K this scan is ~ 1 hour.

d) Small scans in angle. For one central x,y position take ~ 50,000 events at 5 angles (e.g. nominal +/- 2.5 deg and nominal +- 5 deg). In the operating experiment the angle is fixed, however the information from this scan will give another check of the simulation.)

e) Repeat a subset of the above tests with alternative techniques, in particular of QUARTIC light guides. We will have integrated fused silica light guides, air light guides, blackened or highly reflective. These studies will probably be done before (c) and (d), which need only be done with the optimal design.

f) Test timing performance with different electronics, primarily varying the amplification to compare ORTEC 9306 pre-amps with 1 or 2 sets of Phillips amplifiers, and also no amplification.

The above program will require accesses to the area ranging from 10 minutes to 30 minutes to change conditions. In case the CMS Pixel (or other) tests are being done at the same time the experimenters will coordinate access times. However due to limited manpower the experimenters prefer to use the beam for about 12 hours per day and have control.

The experimenters anticipate that after one week of good data taking, the data will be analyzed and perhaps improvements to the detector and electronics will be made, on a time scale of a few months. A further period of beam tests would then be requested.

2.3 SETUP

The apparatus, to be mounted on a 1m long table, consists of 1 or 2 QUARTIC counters, each occupying about 10cm along the beam, and a GASTOF counter about 30 cm long. We will have two small (~ 1cm x 1cm) scintillation counters for an independent coincident trigger, and will use an x-y fiber hodoscope for finer position measurement, if one is available. We will use the beam wire chambers for precision (0.3 mm) tracking.

2.4 ELECTRONICS NEEDS

The experimenters will have 16 channels (from 6mm x 6mm MCP-PMT pixels) for TDC and ADC measurement, which will be either from one QUARTIC module (two rows of 8 in z) or from two modules (1 row of 8 in z each). During concurrent GASTOF tests two of the 16 channels will be used for the GASTOF MCP-PMTs.

A list of electronic units required, and those the experimenters already have, is given in Appendix II

2.5 SCHEDULE

The experimenters propose to begin installing the equipment and setting up the electronics in mid-July, and take data July 24 – 31st. The experimenters can co-exist with upstream users (e.g. CMS pixel) time-sharing on a daily basis as mutually convenient.

III. RESPONSIBILITIES BY INSTITUTION - NON FERMILAB

([] denotes replacement cost of existing hardware.)

3.1 Univ. Alberta : Setting up electronics. [$3 K]

3.2 UTA: Integrating detectors in readout, providing fused silica bars and much of electronics. Test beam coordination. [$27 K]

3.3 Univ. Louvain: Helping with electronics setup. Constructing GASTOF prototype. [$30K]

Total: $60 K

IV. RESPONSIBILITIES BY INSTITUTION – FERMILAB

4.1 FERMILAB ACCELERATOR DIVISIONS:

4.1.1 Use of MTest beam as outlined in Section 2.

4.1.2 Maintenance of all existing standard beam line elements (SWICs, loss monitors, etc) instrumentation, controls, clock distribution, and power supplies.

4.1.3 A scalar or beam counter signal should be made available in the counting house.

4.1.4 Reasonable access to the experimenters’ equipment in the test beam.

4.1.5 The test beam energy and beam line elements will be under the control of the AD Operations Department Main Control Room (MCR).

4.1.6 Position and focus of the beam on the experimental devices under test will be under control of MCR. Control of secondary devices that provide these functions will be delegated to the experimenters as long as it does not violate the Shielding Assessment or provide potential for significant equipment damage.

4.1.7 The integrated effect of running this and other SY120 beams will not reduce the antiproton stacking rate or protons on target for NUMI by more than 5%

globally, with the details of scheduling to be worked out between the experimenters and the Office of Program Planning.

4.2 FERMILAB PARTICLE PHYSICS DIVISION

4.2.1 The test-beam efforts in this MOU will make use of the Meson Test Beam Facility. Requirements for the beam and user facilities are given in Section 2. The Fermilab Particle Physics Division will be responsible for coordinating overall activities in the MTest beam-line, including use of the user beam-line controls, readout of the beam-line detectors, and MTest gateway computer. [0.5 person weeks]

4.2.2 LINUX box computing support as needed (J. Ormes).[0.5 person weeks]

4.2.3 The PPD Mechanical Department shall help provide a table or cart upon which the counter assembly is mounted. The cart needs to provide vertical as well as horizontal motion. They will make modifications to mount the counter assembly and stabilize the load and to provide linear motion. [1 person-week; $1K]

4.3 FERMILAB COMPUTING DIVISION

4.3.1 Ethernet and printers should be available in the counting house.

4.3.2 Connection to beams control console and remote logging (ACNET) should be made available in the counting house.

4.3.3 Assistance with setup of CAMAC system. [0.5 person weeks]

4.3.4 See Appendix II for summary of PREP equipment pool needs.

4.4 FERMILAB ES&H SECTION

4.4.1 Assistance with safety reviews.

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V. Summary of Costs

Source of Funds [$K]	**Equipment**	**Operating**	**Personnel** (person-weeks)
Particle Physics Division	$1.0 K	$0 K	2.0
Accelerator Division	0	0	0
Computing Division	0	0	0.5
Totals Fermilab	$1.0 K	0	2.5
Totals Non-Fermilab	[$60 K]	0	15.0

VI. SPECIAL CONSIDERATIONS

6.1 The responsibilities of the Leader of the FP420 Fast Timing group and the procedures to be followed by experimenters are found in the Fermilab publication "Procedures for Experimenters": (http://www.fnal.gov/directorate/documents/index.html). The Physicist in charge agrees to those responsibilities and to follow the described procedures.

6.2 To carry out the experiment a number of Environmental, Safety and Health (ES&H) reviews are necessary. This includes creating an Operational Readiness Clearance document in conjunction with the standing Particle Physics Division committee. The spokesman of the FP420 Fast Timing group will follow those procedures in a timely manner, as well as any other requirements put forth by the division's safety officer.

6.3 The spokesman of the FP420 Fast Timing group will ensure that at least one person is present at the Meson Test Beam Facility whenever beam is delivered and that this person is knowledgeable about the experiment's hazards.

6.4 All regulations concerning radioactive sources will be followed. No radioactive sources will be carried onto the site or moved without the approval of the Fermilab ES&H section.

6.5 All items in the Fermilab Policy on Computing will be followed by the experimenters. (http://computing.fnal.gov/cd/policy/cpolicy.pdf).

6.6 The spokesman of the FP420 Fast Timing group will undertake to ensure that no PREP or computing equipment be transferred from the experiment to another use except with the approval of and through the mechanism provided by the Computing Division management. They also undertake to ensure that no modifications of PREP equipment take place without the knowledge and consent of the Computing Division management.

6.7 The FP420 Fast Timing group will be responsible for maintaining and repairing both the electronics and the computing hardware supplied by them for the experiment. Any items for which the experiment requests that Fermilab performs maintenance and repair should appear explicitly in this agreement.

6.8 At the completion of the experiment:

6.8.1 The spokesman of the FP420 Fast Timing group is responsible for the return of all PREP equipment, computing equipment and non-PREP data acquisition electronics. If the return is not completed after a period of one year after the end of running the spokesman of the Iowa group will be required to furnish, in writing, an explanation for any non-return.

6.8.2 The experimenters agree to remove their experimental equipment as the Laboratory requests them to. They agree to remove it expeditiously and in compliance with all ES&H requirements, including those related to transportation. All the expenses and personnel for the removal will be borne by the experimenters.

6.8.3 The experimenters will assist the Fermilab Divisions and Sections with the disposition of any articles left in the offices they occupied.

6.8.4 An experimenter will be available to report on the test beam effort at a Fermilab All Experimenters Meeting.

SIGNATURES:

_________________________________ / / 2006
Andrew Brandt, Univ. Texas Arlington

_______________________________________ / / 2006
Greg Bock, Particle Physics Division

_______________________________________ / / 2006
Roger Dixon, Accelerator Division

_______________________________________ / / 2006
Robert Tschirhart, Computing Division

_______________________________________ / / 2006
William Griffing, ES&H Section

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Hugh Montgomery, Associate Director, Fermilab

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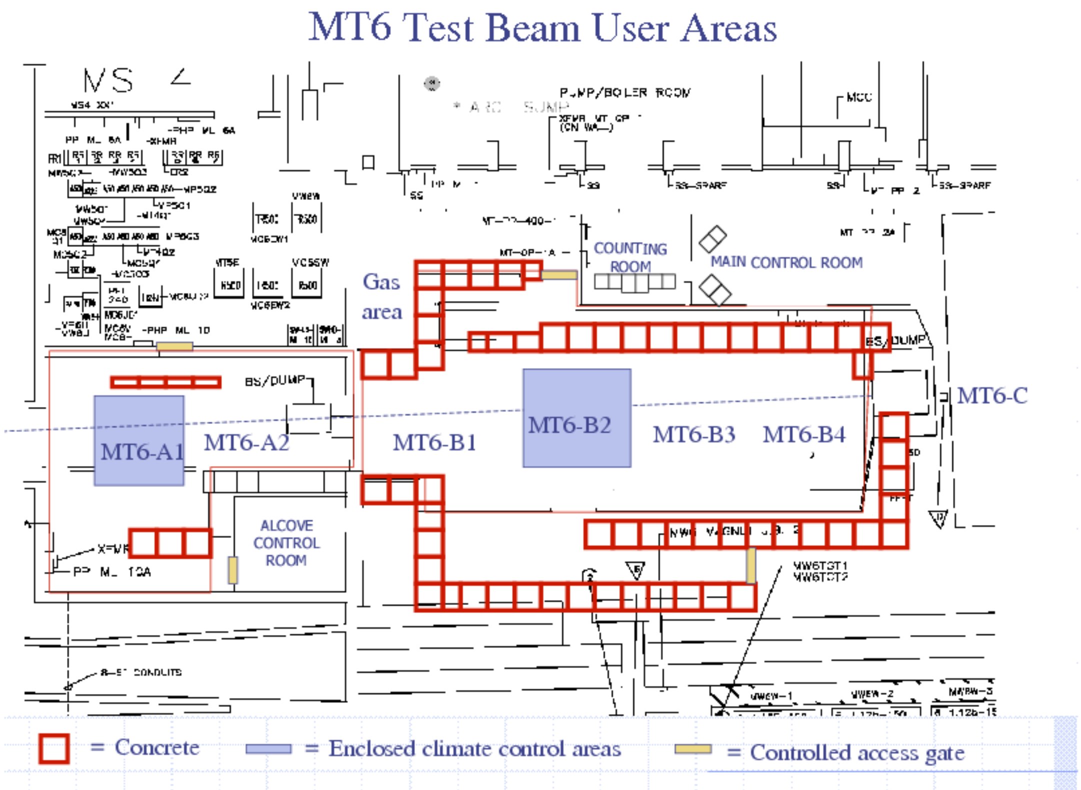
Steven Holmes, Associate Director, Fermilab

APPENDIX I: MTEST LAYOUT WITH POTENTIAL APPARATUS LOCATION

The apparatus could be tested in the MT6-B2 or MT6-B3 area, as shown below.



APPENDIX II: FP420 FAST TIMING TESTS– EQUIPMENT NEEDS

Provided by experimenters:
UTA:
4 MCP-PMT
16 Ch Phillips 7168 TDC
2 ORTEC 9306 Preamps
Fused silica bars
Louvain:
6KV N470 CAEN (HV for MCP-PMT)
2 MCP-PMT for GASTOF
1-2 GASTOF (gas Cerenkov detector)
16 ch Phillips amplifier boards
CAEN V1290a TDC
Alberta:
Air light guides, frame for QUARTIC Detector
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Equipment Pool and PPD items needed for Fermilab test beam, on the first day of setup.

Quantity	Description
PREP equipment pool:	
2	Camac Lecroy 2249 ADC
5	Phillips 715 or Ortec 934 Constant fraction discriminator
2	NIM Octal discriminators Lecroy 623B
1	Lecroy 2323 Camac dual gate generator
4	Visual scaler channels with presets
1	NIM gate generators Philips 794 or similar
2	NIM 12-signal amplifiers Lecroy 612 or similar
2	NIM quad-coin. 2-fold logic Lecroy 621/622 or similar
8	NIM dual delay modules to delay the 16 MC-PMT signals to the ADCs
1	fast oscilloscope
1	VME crate and VME/CAMAC interface
PPD MTBF support items:	
1	Nim crates, powered
1	Camac crate, powered, with controller
	Miscellaneous lemo cables

APPENDIX III - HAZARD IDENTIFICATION CHECKLIST

Items for which there is anticipated need have been checked

Cryogenics		**Electrical Equipment**		**Hazardous/Toxic Materials**	
	Beam line magnets		Cryo/Electrical devices		List hazardous/toxic materials
	Analysis magnets		capacitor banks		planned for use in a beam line or experimental enclosure:
	Target	X	high voltage		
	Bubble chamber		exposed equipment over 50 V		
Pressure Vessels		**Flammable Gases or Liquids**			
	inside diameter	Type:			
	operating pressure	Flow rate:			
	window material	Capacity:			
	window thickness	**Radioactive Sources**			
Vacuum Vessels			permanent installation	**Target Materials**	
	inside diameter		temporary use		Beryllium (Be)
	operating pressure	Type:			Lithium (Li)
	window material	Strength:			Mercury (Hg)
	window thickness	**Hazardous Chemicals**			Lead (Pb)
Lasers			Cyanide plating materials		Tungsten (W)
	Permanent installation		Scintillation Oil		Uranium (U)
	Temporary installation		PCBs		Other
	Calibration		Methane	**Mechanical Structures**	
	Alignment		TMAE	X	Lifting devices
type:			TEA	X	Motion controllers - manual
Wattage:			photographic developers		scaffolding/elevated platforms
class:			Other: Activated Water?		Others